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Comment on "Dephasing of conduction electrons due to zero-point fluctuation"

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It is recently proposed by Wang *et al.* [Phys. Rev. B **61**, R5090 (2000)] that dephasing of conduction electrons due to zero-point fluctuation of electromagnetic field in a vacuum can well account for the measured saturation of electron dephasing time at $T \rightarrow 0$ in various materials. We point out that this calculation is numerically incorrect, while we also provide arguments showing that zero-point fluctuation of electromagnetic field does not cause any dephasing within this theory of Wang *et al.*

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Recently, Wang and co-workers[1] have proposed a theoretical model for the dephasing of conduction-electron wave functions in disordered metals. They argued that the zero-point fluctuation of electromagnetic field in vacuum can cause phase breaking of the conduction-electron wave function. According to their theory, the dephasing originates from the accumulation of a random Aharonov-Bohm phase of a conduction electron in the presence of an electromagnetic field, or, more precisely, a vector potential **A** whose amplitude fluctuates randomly and independently in time and space. Wang *et al.* have reached an explicit expression for the electron-dephasing time at zero temperature $\tau_\phi(T \rightarrow 0\ \mathrm{K})$; they predicted a $\tau_\phi(T \rightarrow 0\ \mathrm{K})$ linearly dependent on the electron-diffusion constant D, a material and/or sample parameter. Wang *et al.* also argued that their theoretical value agrees well with the observed saturated dephasing times in various experiments.[2,3] Unfortunately, we point out below that their theory and the agreement between their calculation and experiment are simply fortuitous.

Theoretically, the zero-point fluctuation of electromagnetic field (EMF) does not actually cause any dephasing of electrons, as argued in the following. The interaction of EMF with an electron is, for example, to the order of e^2 represented by the diagram as shown in Fig. 1, which only renormalizes the electron propagator. According to standard relativistic quantum mechanics,[4] inclusion of the diagram is equivalent to replacing the propagator of a bare electron by that of a physical (or dressed) one. The physical electron may decay radiatively if it is in an excited state (i.e., the energy denominator of the propagator has a finite imaginary part), or may not if it is in the ground state (as is the case for conduction electrons at zero temperature). In the latter case, the renormalized propagator is basically of the form for a noninteracting electron, which does not dephase. This is in contradiction with the result of Wang *et al.*[1] It is our opinion that in the dephasing calculation of Wang *et al.*, the interaction between the EMF and a dressed electron is spurious, since it is already included in the renormalized propagator of the electron. Therefore, the dephasing that results from the spurious interaction cannot exist.

FIG. 1. O(e^2) correction to the electron propagator. Solid line: bare electron propagator, wavy line: photon propagator.

Numerically, the fortuitous agreement between the calculation of Wang *et al.* and experiment, results from their use of a well-overestimated value of the electron-diffusion constant D. In typical disordered metals, D is of the order of $\sim 10^{-4}-10^{-2}\ \mathrm{m^2/s}$ (corresponding to the electron elastic mean free path of the order of a few to several hundreds of angstroms).[2,3] However, Wang *et al.* used a value $D \sim 10^{4}\ \mathrm{m^2/s}$ in their theoretical evaluation of $\tau_\phi(T \rightarrow 0\ \mathrm{K})$, resulting in a fortuitous agreement between their theory and experiment. If a correct value of D were used, the theory of Wang *et al.* would predict a saturated dephasing time $\tau_\phi(T \rightarrow 0\ \mathrm{K}) \sim 10^{-20}$-$10^{-18}$ s [as opposed to $\tau_\phi(T \rightarrow 0\ \mathrm{K}) \sim 10^{-12}$ s evaluated in Ref. 1]. This value is *at least six orders of magnitude lower* than the experimental value.[2,3]

In short, the calculation of Wang *et al.* is clearly incorrect, both theoretically and numerically.

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[2] P. Mohanty, E.M.Q. Jariwala, and R.A. Webb, Phys. Rev. Lett. **78**, 3366 (1997).
[3] J.J. Lin and N. Giordano, Phys. Rev. B **35**, 1071 (1987).
[4] See, e.g., J.D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics* (McGraw-Hill, New York, 1995), Sec. 8.5.